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TREASURE HUNTING *of* TODAY

AND

CHEMISTRY IN OUR SCHOOLS

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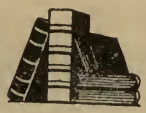

12/7/21

Treasure Hunting of Today

Every one, every man and every woman, every boy and every girl, has let his or her fancy stray at times and wished for power over the matter of the world; has wished for a magic wand that would transform one thing into another; for the philosopher's stone which would turn the common metals into gold; for the subtle elixir by which life could be prolonged as perpetual youth.

The pleasure of reading the wonderful stories of the Arabian Nights is in large part the result of the stimulation that comes to the imagination and leaves us trying to picture what we would do had we Aladdin's lamp or did we know the magic password to hiding places of untold treasures, gold, sapphires, pearls and rubies.

In the same way the stories of the blood-thirsty buccaneers of the Spanish Main leave, beside their interest as yarns of breathless action, a haunting feeling that there must be treasure to be found and that this possibility lends a certain excitement to life's chances.

Of course this feeling, which is so strong upon us when we finish reading one of these tales of adventure in the quiet of the evening, is apt to fade after a sleep, and in the light of the morning the romance seems to vanish; but down in our hearts we always have with us that longing that makes us treasure-hunters.

While all mankind has always longed for such powers, a few have gone treasure-hunting. They have sought to read the riddle of the code, to learn which has meant controlling the forces of nature. They have worked for treasure, but not treasure of gold and jewels; they have sought real knowledge, believing that to know anything for certain which no one knew before and to tell others of it, is one of the best ways to serve the world; wisdom to them has been the supreme treasure.

These men, and women, too, have to those who wished to be up and doing seemed to be wasting their time.

A Captain Kidd could see no earthly use in trying to find out the real nature of a drop of water. Are not the oceans full of water, billions upon billions of drops? But rubies are scarce and they can be stolen. Now the time has come when the men who studied the drop of water can laugh at the Captain Kidds because by their studies they have learned to make real rubies, and sapphires, and emeralds.

Those who have learned the secret of the transformation of matter and energy, who have done in very fact those things which the

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alchemists and the magicians of old hoped to do, and in addition a great many things which the wise men of the past never dreamed of—those men and women have been so busy that they have only had time to tell each other of their results in order to push ahead more quickly into the darkness of the cavern of the many treasures. They have had to make a language to describe the things they have discovered, and they have not taken time to tell everybody what their words mean.

Thus it comes about that humanity has learned to share in the treasures without understanding where they came from or to whose efforts they were due. Still less is there any understanding of the magic transformations and the fact that they are magical in results only, the methods being an open book.

The hiding-places of modern treasures are so strange that they can not be found by chance:

> Silk hidden in the fibre of the cotton; exquisite dyes and perfumes in a pot of tar; bright metal in common clay; the strength of the volcano in saltpetre; silver in lead; deadly poisons and healing medicines in a lump of coal; food in the air.

It is worth while to learn a little of the way in which the seekers after knowledge have come to gain this power over matter; it is worth while because it helps us to appreciate what the mind can do, and it also is worth while because the treasures discovered are outnumbered by those still hidden, and some of us may be able to take a share in adding to man's power over matter. It is impossible to say where next the treasure may be found: A heap of sawdust; is it merely so much rubbish, or is there hidden in the little fragments of wood something of very real use, to find which would bring honor and wealth besides aiding all mankind?

In the past it is in just such places that wonders have been found.

Play or work, real knowledge comes only of close attention, though not always consciously given. When you watch a game of football or baseball you do not realize that you are doing the hardest kind of studying, but if you are really interested you most certainly are, and only the players are studying harder.

There are many things which can not be understood unless they are taken apart and each portion examined separately. In general, to study an object, to be able to use every sense upon it, it is best to simplify it; to make an engine, one must know the parts of which it is composed and how they are set up; to make a dress, it is necessary to know of what each part is to be made and how each piece is to be cut. Following this plan, the men who have grown to be masters of human destiny have never been content to take anything in hand without trying to simplify

it in order to understand it. The chemist has always insisted on knowing of what things are made, and the physicist how they are constructed. What is there about the structure of air that makes it act like a spring in a pneumatic tire? Such a question the physicist asks. It may count a small matter, but in this case to be able to answer is to know the structure of all things. The chemist keeps asking: Can rust be taken apart? What is it made of? Is there anything in the world that cannot be made simpler? Such questions seem far from the practical needs of every-day life, but by putting them and experimenting until the answers were found man has learned wonders.

Draw a breath. You have inhaled 3,000,000,000,000,000,000,000 little particles of air, a jostling, pushing crowd of oxygen and nitrogen particles so crowded that each one bumps his neighbors and is bumped back five billion times every second, each trying to rush 1,500 feet in that time. Exhale, and out rush an equal number of molecules, but 120,000,000,000,000,000,000 oxygen particles that went in do not come out, while their places are taken by carbon dioxide and water that came out of your body. Weigh the crowd coming out and it will be found heavier than that which went in. You are losing weight with every breath. Drink a glass of water and you have swallowed 1,865,000,000,000,000,000,000,000 molecules of water. Somehow, out of all the myriads of molecules that you eat and breathe, you get yourself made and keep your body running.

All matter is composed of such trifling particles. A ton of steel is made up of fragments so minute that a thousand million million are needed to form the point of a needle. But each kind of matter, if different under like conditions, is composed of different molecule units. Units of water, units of iron, of sugar, of salt, of diamond, of sulfur. Small as these molecules are they are usually not simple but are composed of simpler particles, the atoms. Can you imagine the physicist and chemist pulling matter to pieces, nearly hopeless at the complexity, but still hoping to reach an understanding?

Millions of different kinds of substances, millions of different kinds of molecules, and, if these are complex, then tons of millions of different atoms. That was to be expected; but in reality it was found that there are only some 80 different kinds of atoms, and that a fourth of that many form the great majority of molecules. Moreover, rarely are there more than three or four different kinds of atoms in any one kind of molecule.

Have patience for a moment; we are very near the secret of the transformation of matter.

If each substance is composed of characteristic molecules, and there

are millions of different kinds, and if the only things in molecules are atoms, and there are only 80 of these, then the difference in molecules must be the outcome of either the number, arrangement, or kind, of atom, and since there are so few different kinds of atoms, the number and arrangement must be the chief thing. Then, and this is the great secret, to learn how to rearrange atoms is to learn how to transform matter.

An analogy may make the condition clearer. There are millions of buildings in this world, but there are not millions of building materials used. The difference between one structure and the other is caused by the arrangement, first; by the material, second; a castle may be of some masonry, so may a hovel.

The chemist has learned to know the bricks, stone, and mortar of molecules, and he has learned how to duplicate nature's molecule-structures and also to make new ones, though in every case he is limited by the properties of his building-materials, the atoms, just as the builder is who cannot erect a sky-scraper of bricks or lumber.

To measure the progress of the past hundred years which has come of the advance of chemistry, it is well to contrast the present with the past. Because of its great importance to everyone, the supply of food may serve as an example.

Let us go back to mediaeval times and assume that a chemist with his present knowledge is a citizen of a beleaguered castle. The enemy have surrounded the walls on all sides and the garrison and civil population, swelled by the peasants from the country-side, are beginning to worry about the food-supply. The chieftain would call in his chemist, remembering that this unassuming man had suggested certain precautions to be taken in case of siege.

"Sire," the chemist would say, "within these walls we have a generous waterfall which never dries and is fed from a spring; it is out of the clutches of our foes; we have abundant wood, and coal, and the air no enemy can take from us. In addition, because you had faith in my wisdom, we have many tons of paraffin, much sulfur and lime. You will remember that these things I said would be necessary for my plans in case of siege. Our bins are full of dried potatoes, harvested and dried when our corn failed. I, on my part, have certain simple salts, such as the phosphate of potash. Because of the diligence of my servants, all the necessary equipment is in readiness; therefore I will obey your request and feed the people."

Then would ensue a busy scene. Certain men would take some of the billets of wood and convert them into sawdust, using a machine run

by the power of the waterfall. Others would burn some of the sulfur and lead the fumes through a contrivance like a jacketed length of iron pipe in which was some platinum supported on asbestos. In a little while white fumes would be formed and these would be caused to unite with water to form sulfuric acid, or oil of vitriol.

Sawdust and sulphuric acid would be put into a great vessel and steam injected, the boiler being heated by the burning of some of the coal. Then cold water would be thrown in to stop the action of the acid. The sawdust would look about the same, but there would be less of it and the acid liquid would contain sugar made from the sawdust. Lime would take out the acid and part of the filtered liquor would be evaporated to a sticky sweet mass by no means unpalatable, being, in fact, something like corn syrup; that would go into the food stores as a sugar substitute—not very sweet but useful.

Here the interest turns to another group who are busy on a very different task. They are liquifying air, and allowing the liquid to boil, which it does at 383° below zero. The gas coming off first would be nitrogen and it would be stored in special gas holders. The remaining oxygen would also be stored.

Yet another group would be making hydrogen and oxygen from water by means of electric current obtained from the waterfall. The hydrogen they would pass on to those who had made the nitrogen, who would mix two gases in a definite ratio and heat them in a vessel under pressure with some uranium. This would transform the mixture into ammonia. Some of this would be reserved, the rest burned to nitric acid in another special apparatus. Nitric acid and ammonia would be brought together to give ammonium nitrate.

By this time the populace would say: "Truly the chemist does wonderful things but we see our dinners no nearer. We will have patience, however, and give him every help; if he fails we all die; but we will do that anyway if food is not forthcoming and the castle falls."

In the meantime great vats would be filled with the sweetish liquor from the sawdust and some of the ammonium nitrate added to this, also a very little potassium phosphate. The liquor would be sterilized by steam, and while it was being cooled the chemist would hurry to the house of his intimate friend the biologist. (Scientists of different kinds always have to work together to get good results.)

"Good Worthy," he would say, "all is in readiness. The truth of your discoveries, which I doubt not at all, will be tested in practice."

The biologist would take him to a kind of ice box and point proudly to certain gray masses therein.

"Behold, Sir Chemist, the little servants are ready. Carefully have

I reared them. They are no ordinary yeast cells, but wonder workers that will make meat for the people out of ammonium nitrate which you make from air and water. I will gather some up to take with us."

Then would they put the special yeast into the sawdust sugar syrup with the ammonium nitrate in it. The yeast would grow apace and in a short time it would be gathered and pressed free of liquid. It would then be treated by the chemist in such a way that the curious taste would be replaced by a pleasanter one. Then it would be given to the people to eat in place of meat, being very nourishing even though made from air and sawdust.

"But," the people would object, "your meat is without fat, and fat we must have if we are to do hard work."

"Have patience," the chemist would reply, "the fat is being made, it isn't quite ready today, but there will be plenty from tomorrow on."

And he would keep his word; he would take some more of the sugar water made from shavings and add mineral salts to it, then he would call upon the worthy biologist once more, saying:

"Gentle sir; I am now ready for your glycerine fungus."

"Good colleague, again am I ready, having forseen your request. Here is my noble race of plants which convert sugar into glycerine."

Together they would do all that was necessary and the sugar would disappear from the syrup, its place being taken by glycerine among other things. The glycerine would be obtained pure by distillation.

In the meantime, great big lumps of paraffin, which the chemist had caused to be brought within the walls, would be heated in closed vessels with some of the oxygen obtained from the water when the hydrogen was made. The paraffin would turn into a sour mass which in the chemist's hands could be purified and would yield acids which, when combined with the glycerine made from sawdust, would give fats like butter, lard, or tallow.

Thus, you see, the citizens and garrison could be fed on meat, fat, and sugar. The starch of their diet would have to come from the dried potatoes, which you will remember were stored at the chemist's suggestion. Thus the beleagured could hold out.

This sounds like a fairy tale, mere idle imagining of what might be. It is not that. A great nation faced by famine, helped feed her people by such means. What was done sufficed to show that there is nothing to prevent the perfection of methods which will add to the food resources of mankind enormously. Great vats will take the place of the cattle ranges, yeast cells that of the cattle. It is true that the little yeast plants seem insignificant, but they mature in a few hours and they multiply at an enormous rate. Already yeast food factories

created during the stress of war are operating in time of peace. They will increase in numbers and in them will be made better, more excellent products as the industry develops.

This has come because the path of the magician has been abandoned and his place taken by men and women who know how molecules are made.

If everything you touch were to tell you whether or not it owes its existence to the chemist you would learn very soon of the tremendous importance of the man who makes molecules.

Having spoken of food, a start may be made in the kitchen.

As you strike a match it calls out that its head is made from bones and sulfur and fish glue, under the chemist's direction, that its stick is soaked in alum to prevent it glowing, alum made from a mineral called Bauxite.

As the gas is turned on it whistles that it is made from coal, and water, and coke, and that its making is controlled by the chemist. The gas range goes back to the iron ore of Lake Michigan from which it was made in the Pittsburgh blast furnaces. Again a transformation of matter. The aluminum kettle comes from aluminum oxide dissolved in molten cryolite from Greenland and decomposed by tremendous electric current generated by the falling water of Niagara.

So far everything handled has been matter made by the chemist and not found in nature.

If the task in the kitchen is to make some biscuits, then it would seem that the actual materials to be cooked, would be beyond the range of applied chemistry. But the chances are that the flour comes from wheat that was disinfected with formaldehyde and fertilized with phosphate. The flour itself was bleached chemically. The milk used is untouched by the chemist, except to test it, but the salt is prepared under his supervision. The baking powder is entirely his handiwork. He made the bicarbonate in it from ordinary salt and the alum or phosphate from mineral matter; if the powder is made from tartaric acid, then he has to admit that he has not found a cheap way of making that, but he will have one soon, and then that too will be made. The tin the baking powder is in is also an entirely artificial product.

The truth is that the shadow of the chemist is over all that comes into the household for food. If his efforts do not contribute directly, they do indirectly because his knowledge stands between the thief and the profit to be stolen by the adulteration of food.

Every girl should know the chemist as her friend, because it will enable her to help him to serve her, and because it will make the surroundings of the home much more interesting. There is a fascinating

story in everything used. And besides, most women are engaged in applying chemistry all the days of their lives, and they can learn to do things very much better with more understanding if they learn why they are doing them. Feeding the young and old, nursing the sick, the care of the house, the treatment of textiles, all these are based on the facts of chemistry.

Chemistry is profoundly important, and fascinatingly interesting. To learn something of the facts which the chemist has to interpret and to learn how this knowledge is put to use is to become better acquainted with the wonders of life; it is the key to the gateway into a new region; to have it is almost the same as to have a new sense, the sense of matter. To be without this sense is to be blind to a very great deal that makes one's surroundings interesting and one's life rich. Neglect this aspect of nature altogether and it follows that you elect to walk in darkness in places where it would be easy to see. You will be like those who always travel from one place to another, between which lie beautiful scenes, but choose their hour of going in such a way as to cause them pass all the beauty, all the interesting scenes, at night. Those who do not know how much they miss cannot be blamed for thinking that the scenery they pass through is probably not worth looking at, being very much like the surroundings they leave and those they reach.

In order to give you some chance to describe this for yourselves, the best plan is to describe some of the interest and beauty of that land which so few know. Then, perhaps, you will choose wisely and arrange that you will pass through the land of chemistry in your journey, though not with your eyes closed, but where all is brightly lighted by the sun of understanding. You will profit and all mankind with you.

Human beings, as machines, are limited by their physical development. There are a great many degrees of muscular strength, from the strong man to the helpless invalid, but strength is desirable. In the days of the cave men, the limit of strength was simply the power of the strongest man. When the cave man wanted to make a home, he had to take what nature gave him. He had no means of making holes in cliffs, even the strongest could not hope to hew out a cave. Now man uses the locomotive which has the strength of thousands of men and he is able to do this because he applies chemistry to the extraction of iron and its conversion into steel. A wooden or stone engine would not be much use. Now man's arm is made strong by explosives; dynamite from glycerine, ammonium nitrate from the air, guncotton from the air and cotton. He can shatter great cliffs and bring them tumbling

in hundreds of torn fragments to their base, he can blow to pieces rocks that menace his ships, he can pierce mountain ranges and bring nations together, and he can make the oceans meet. How is iron taken from the rust-like ores which are dug from the earth? How is iron turned into steel? Why are explosives so powerful? How are they made? Such questions chemistry only can answer.

To lose one's sight, to be blind, has always been thought one of the greatest misfortunes that could befall a human being. It is true, and it is equally true that to extend human vision means adding to the wealth of life. Chemistry has done this in a great many ways. First of all, in the photograph it has made it possible for you to see, even though you were not near the object you view. Stop to think for a moment of the many scenes, the many places which you feel you know, which you feel are in a sense a part of your surroundings, yet which you have never seen except in pictures. Pictures may be great art, that is, the highest type of picture, but great art of its very nature must be rare, and can, therefore, depict but little of all there is of interest in the world. The camera may produce something which is not great art, but which is a truthful record of what can be seen upon the earth. This record is made so cheaply that it is viewed by millions who would never see the subject photographed. Besides making it possible for people to see distant scenes, the chemist's art, applied to pictures, has made it possible for millions to see the tragedies and comedies of the movie. Here the chemist has functioned not only in making it possible to record the effects of light, that is, taking the pictures, but also by mounting these on a flexible transparent film which makes it possible to project them very rapidly one after the other upon the screen.

Another widening of vision has come of the joint efforts of physicists and chemists. The physicist has produced rays which pass through a great many kinds of matter which are opaque to ordinary light. The chemist has made it possible to convert these rays into visible ones. In consequence of this, you can stand in front of the X-ray tube and see the beating of your heart.

Just recently, a substance which the chemist produced years ago, promises to make it possible to send pictures over wires just as we now send words. Already the newspapers have published illustrations sent more than a thousand miles, a whole picture being transmitted in eight minutes.

In addition to this, the coming of photographic methods of making pictures has made it possible for man to see things which he never could have seen with his naked eye. Pictures of the moving parts of engines can be taken in such a minute fraction of time that the eye would be

utterly unable to form a mental image of it. Pictures have been made in one-millionth of a second. Thousands of these could be made in the time it takes the human eye to get any impression at all.

Light effects, too feeble for vision, have been allowed to fall persistently on the photographic plate. In this way, we have detected millions of stars which we could never possibly have seen because the effect of their light is not sufficient unless it is stored up in successive small quantities until it produces a visible effect.

The photographic plate is peculiar in other ways. It is sensitive to waves which we cannot recognize as light and on this account we are able to take photographs produced by invisible light and therefore different from those seen by our senses.

How is light caught as a picture on a photographic plate? How are negatives developed, and prints made? How is film made? It is necessary to learn something of chemistry in order to understand.

Our eyes have seen strange things because of the results of chemistry; our ears have been given more to hear. Everywhere throughout the length and breadth of the land, the same human voice may be heard at the same time by means of the phonograph and this instrument is in a great measure successful because of the material which the chemist has placed at the disposal of the inventor of the mechanism, more especially for the making of the discs. Of what are phonograph records made? In a moment you will be told.

We may gain a further notion of the value of applied chemistry if we think of those things which occur in nature and then consider those into which the chemist can transform them. Wood is probably the most common vegetable product. Mechanically, this can be made into a great number of useful articles, but all of them are still characteristically wooden. The chemist converts wood into wood pulp, and wood pulp makes possible the daily newspaper. From the material which he takes out of the wood in making the paper, he is finding it possible to make alcohol, not wood alcohol, but grain alcohol. From the wood pulp, he can go to artificial silk, which is more lustrous than the natural. Again, during the war, it was found that wood pulp could be used instead of cotton in making guncotton, and that means that it can be used also for the production of collodion and articles made from collodion, such as celluloid.

The fact that wood could be transformed into a very different product, charcoal, when heated out of contact with air was one known from remote antiquity. The gases that escaped were of no consequence to the charcoal burners in the forests of old. The whole operation was considered so menial that only the very lowest class in the population

attended to it. In more recent times, the chemist has found that these vapors which escape are of very considerable value. From them we obtain wood alcohol which finds a very extended use as a solvent. Together with this wood alcohol, we obtain acetic acid, the characteristic sour principle of vinegar. This is used for making white lead, for example, and for coating the wings of airplanes. Once having the wood alcohol, we find it possible to make formaldehyde, the solution of which is sold by the druggist as formalin. Formalin, as you know, if you have allowed any of it to come in contact with your skin, toughens animal matter and renders it horny. Apparently, this happens also to those micro-organisms which cause disease or promote putrefaction, and formaldehyde, therefore, makes an excellent disinfectant. But it is used for a great many other things; used for substances which seem very remote from wood distillation. For instance, most phonograph records are made on a substance which results from the interaction of formaldehyde and carbolic acid. Artificial ivory can be made from formaldehyde and cheese.

Cotton is another abundant vegetable product. The seed hairs of this have been gathered from ancient times. These fibers have been woven into cloth. Beyond that, very little has been done with it until recent years. Now cotton is made into guncotton, the explosive; into collodion, which is used in making lacquers; into celluloid; into vulcanized fiber; into parchment and a great many other materials, and the seed itself is made to yield riches.

Out of the earth's crust, out of the sand, and clay, and rocks, chemical methods applied knowingly or blindly have enabled man to obtain new materials of great value.

All the metals, save only gold and platinum and sometimes copper, are found in the form of ores, which, in themselves, are no more valuable than any heavy stone. Iron pours out at the base of the blast furnace; copper, silver, and lead are extracted from their ores in the smelter. Tin, zinc, aluminum—the value of these all can realize, but there are many other metals of which less is heard. Many of them have been produced in commercial quantities only in recent years, but already they are indispensable; magnesium, which makes it possible to take pictures by flashlight; tungsten, which enables us to turn small quantities of electricity into light as in the pocket flash, or large quantities more economically, as in the indandescent bulb; vanadium, chromium, molybdenum, their very names are hardly known, but when added to steel they make new and wonderful metal mixtures possible; some so hard that high speed tools made of them can be used to chisel ordinary steel even when these tools are red hot from friction. Already these

rarer metals have given us rustless knives. Yet all this is a beginning. There is no reason to suppose that the possibilities have been exhausted. The whole thing depends on the chemist making the extraction of these rare metals cheap enough. He has already done that in the case of aluminium. Sixty years ago, the metal could be had in small quantities at a price of about $140 a pound. Now it sells at 23 cents, and is available in any quantity. That, by the way, is the achievement of a young man, little more than a boy, who was caught by the interest of chemistry. A discovery such as that makes a life worth living. Like all such advances, it leads to unexpected results. For example, in this case, cheap aluminium has made it possible to fuse great castings together, not by using the metal as such, but by using the enormous heat with which it burns; it gives us a little local furnace hot enough to melt iron.

But instead of trying to thing of some of the uses made of metals, let us try to think what is would be like if we had none of them. The structure of civilization would collapse; railroads, steamships, telegraphs, and telephones, automobiles, kitchen ranges, knives and scissors, nails and pins, skyscrapers and bridges all would vanish.

But metals are not all that the chemist makes of the materials in the earth's crust. He makes cement from limestone and clay; soda from salt; fertilizer from the bones of long extinct animals; acid from sulfur; dyes and drugs from coal.

Dyes and drugs from coal! That is perhaps the best illustration of all to show how unexpected are the hiding places of treasures. The story of this success is a long one; it is still being written; a fascinating yarn as full of adventure as those of Robert Louis Stevenson. The plot may be outlined in a few words.

Black coal is material formed from the wood and peat of the swamp-forests of millions of years ago. It was long before it was used as a fuel because nobody thought of burning what looked like stone, still longer before it was used for making coal gas and until that time no coal tar was saved.

It is easy to understand what coal tar is. When a shovelful of soft coal is thrown on to a fire it does not burst into flame, but a cloud of smoke comes off as can be seen when the fireman throws coal into the fire box of a locomotive. In a few moments, when once the fresh coal is burning no more heavy smoke appears. The smoke comes of heating the coal without burning it. The surest way of doing this is to put the coal in a pot and put this on the fire; if the pot has a small outlet the smoke pours out through this. Allow the smoke to pass through a long tube and most of it will settle, though gas still keeps coming out.

This gas, when made on a large scale, is purified and distributed as illuminating gas through the city mains.

In the tube there is a mixture of tar and water containing ammonia. The tar is an evil smelling sticky substance, a thing of no apparent value whatever. However, the chemist does not hesitate to examine a substance because it looks nasty. In this case he found that coal tar was a mixture of things which could be separated pretty well by boiling the tar, collecting what distilled over in portions, and repeating the distillation. In 1843, by such a study, a substance called aniline was discovered. Twenty-one years later a boy who was tremendously interested in chemistry wanted to make quinine artificially. All he knew about it was that it had certain properties a very little like those of aniline, but that it contained oxygen which aniline does not. He tried to convert aniline into quinine by putting in oxygen. He noticed that he obtained a brightly colored material. He tested this and found it to be a bright violet-mauve dye. This discovery created a sensation because it showed that dyes could be made instead of taken from plants, and also because the discovery soon led to the making of much more brilliant dyes than any natural ones.

Aniline is present only in very small amounts in coal tar, but even before the work of young Perkin, it had been found possible to make aniline from one of the oils, benzene, which is relatively abundant in coal tar.

Besides this oil, there are the others, and three solids, one of which is naphthalene, which you know as moth balls. Here were six new kinds of molecules to experiment with and the work went ahead with great vigor because the molecules interested the scientist on the one hand and the business man on the other, the latter because the making of dyes became very profitable.

Soon the chemist knew so much of the subject that he decided to try his hand at making dyes which were till then found only in plants. He started on Turkey Red and soon found he could make that from coal tar. Then he went on to indigo; it took him twenty years to solve that problem, but it was done and now practically all blue overalls are dyed with indigo made from coal.

In addition to these successes, work was being done on making medicines from coal and this, too, very soon resulted in great achievements. For example, salicylic acid is the best thing for rheumatism, but it is found in nature only in the oil of the little wintergreen plant. There is not enough wintergreen to furnish a supply sufficient to make salicylic acid cheap. The chemist takes carbolic acid, of which there is quite a quantity in coal tar, mixes it with lye, and heats it with carbon

dioxide under pressure and salicylic acid is made, made so cheaply that poor and rich can use it. This is only one of hundreds of materials of great value which are a direct result of the chemist's work on a waste product.

There is another reason why you would profit by learning something of the methods by which matter is transformed, methods which are not strange or magic, but simply the result of precise observation and clear thinking. This additional reason is that you are in charge of a chemical laboratory; whether you wish it or not, whether you know it or not, from your beginning to the end of your days you are the director of a laboratory and plant. You have lots of assistants who do their business so well that you have not to bother yourself with their actions at most times, but if you do not act intelligently as a director there are times when things will go wrong needlessly. Then you know that your plant is not running as it should because the joy fades out of life and you are very miserable, you are ill. That the body is the seat of complicated chemical changes is very evident. A human being is apt to think of the food eaten as coal put into a furnace; the notion is correct, but only in part; in reality, especially when the body is growing, the food eaten turns into the body, just as though the coal turned into the iron of the furnace. Eat lamb or beef, fish or fowl, corn or buckwheat, provided the variety is sufficient, the result is the same; all of these are used in making human being. A little particle of lamb does not become a little particle of human muscle, otherwise since meat and fish differ appreciably, those living on one would be different human beings from those living on the other. What the body does is very much what the chemist does; the food is broken down into smaller units, the simpler molecules, and built together again into body material. Those who wish to be doctors must know about these things; those who wish to act wisely in the choice of food and in the dieting of the sick should know of the processes going on within the body. Every one can act more wisely in keeping himself in good condition if he knows something of psysiological chemistry.

The chemist has gone so far as to learn the composition of some of those materials which control the changes within us, and in this way he has been able to assist the physician in curing or relieving abnormal conditions by making the very things which the body needs.

In addition he has found it possible to make a great many substances, which are not produced within us, but yet are useful in treating illness. Most of the remedies on the shelves of the family medicine cupboard are made and are not found in nature. The chemist can supply soporifics to induce sleep; anesthetics to make portions or all of the body in-

sensible to pain; stimulants to keep sleep away; materials which will control the pressure of the blood; these are but a few of the materials he supplies as munitions to the physician in his fight on disease.

The war on disease is one that is with us all the time; young and old are attached by bacteria day in and day out. Every time the skin is broken invaders flock into the breach. Usually our natural defenses suffice, but if they do not, then our bodies are invaded and we fall ill to a greater or less extent, depending on the kind of invader and the strength of our second lines of defense. These enemies of ours have always been without scruple; the laws of nations have meant nothing to them. Long ages ago the bacteria of a cold invented a sneeze "gas," the bacillus of lockjaw used a terrible poison on the body cells. Typhoid and scarlet fevers, diphtheria, measles, and all similar infectious diseases are caused by the poisons produced by minute living things that have invaded us. The physician helps us to fight against these attacks and tries to keep us free from them. In his work his ally is the chemist who supplies materials which will either repel the invaders or reinforce our body cells sufficiently to make them victorious. Sometimes the attack is carried into the enemy's country, as in disinfecting the water supply of cities. Some day the chemist hopes to place in the physician's hands materials which are deadly poison to bacteria but harmless to the body. Then infectious disease will lose most of its terror.

In looking forward into life from the school age, there is always one tremendously important subject: the vocation which is to support you and make you useful to yourself and others. There must be all kinds of occupations and within limits the choice of any one is open to you. Among the possibilities is that of being a chemist. Before a choice can be made, it is necessary to know something of the subject. What has been said should show that this branch of knowledge is one that can very well be studied by every one sufficiently to become familiar with the part it plays in life. It is like a universal language which refers to everything everywhere.

As a profession it offers a very wide field. It deals with so many aspects of the utilization of matter that every type of work can be found within its boundaries.

To be a research chemist is to use one's mind in seeking to understand the many unsolved riddles of the transformation of matter; it is to be of distinct use because directly or indirectly it leads to a better control of the forces of nature. To be an industrial plant chemist is to put chemistry to use in controlling plant operations on a large scale; it means the direction of men, as well as matter. To be a physical chemist is to devote attention to the conditions of chemical changes:

this is the best field for one with a liking for mathematics. To be a biological chemist is to devote one's self to the study of the chemistry of living matter; a most fascinating branch of knowledge, which can be pursued either as research or in the practical field.

The fertilizer industry offers a chance to make chemistry useful to the farmer; the application of chemistry to agriculture serves the same end. Farming is now becoming a matter of fertilizers, sprays, disinfectants, and depends more and more on a knowledge of the chemistry of the soil. The packing industry, the making of flour, the preservation of foods, extraction of beet and cane sugar, the utilization of waste products—all these activities which are the industrial working up of the products of the soil call for the services of the chemist.

The making of dyes and drugs is possible only because of the chemist's aid. These industries will need a constant supply of men trained in the science.

The Army will require men for the Chemical Warfare Service, men who will experiment in peace time to make sure that the Nation will be able to defend itself in war.

Chemists will be needed in the industry of making explosives, artificial silk, celluloid and the like. Others will be wanted in the smelters and in the oil refineries of the country. There is really a very great range.

It might appear as though success were certain and as though chemists must be in such great demand that the profession could not be overcrowded. To be quite honest it is necessary to say that there is this fact which makes chemists less in demand than might be expected: When the chemist has discovered a process he can usually make it so simple that any intelligent person can carry it out. Therefore the chemist has to pass on to something else or be paid at the rate of an ordinary unskilled workman. But even so, there is an abundance of good places for good chemists.

What has been said applies chiefly to men, but women also find chemistry very well suited to them as a profession. It does not involve heavy work, it requires great skill, it is very interesting and it applies to everyday life. The combination of biology and chemistry offers perhaps the most excellent opportunity to women.

Another aspect of the subject has been touched upon, but it will bear further emphasis.

To enjoy life to the full you must be able to use your senses to the best possible advantage, which means that you must not only collect impressions, you must interpret them also. But to do no more than use your own senses is to miss a very great deal; you must use the collec-

tive senses of mankind. Then you will really become aware of and enjoy countless facts which would otherwise escape you. Around these facts you can build innumerable happy fancies because an active imagination uses the suggestions that come from reality. Not to possess a cheerful, lively imagination is to go through life sadly, to be afraid of one's own company, to be the slave of chance surroundings.

It is not the keenness of your eyes alone which determines what you see. The interpretation given the sight is just as important. A fine story published in a foreign language which you do not know is to you nothing but a great many groups of letters on paper, it is only what your eye actually sees. In just the same way unless you know the language in which the records of things are written you cannot have any real sense of their meaning and of their beauty.

Look at the scene about you when you are at a picnic or when you are fishing. Overhead the green leaves rustle as the breeze moves them; what are they to you as you gaze up at them? Merely pretty green shapes against the bright sky? Trifles of no interest to a live boy or girl?

A house in which bombs were being manufactured would look as uninteresting as the next until the detectives, following each little clue, told the story of what was going on within. In those leaves there are countless workers making stranger things than bombs. In those leaves we know, because of the work of the detectives in the service of botany and chemistry, that there is being made living matter out of dead, coal from ashes and flue gases. We are accustomed to the knowledge that all things die and disappear, but we give no thought to the coming into existence, not of each living thing, but of living matter. But *no animal* can turn those things, into which living things pass, back into the material of life. Yet it must be done or else life would cease. Look at those frail leaves with the eyes of the botanist and chemist and they become factories like countless billions of others wherein are made the things which make life possible. Stop all the myriad cells of the leaf and grass blade and within a few months the beginning of the end would be with us. A year, two years at most, and all would be dead except for toadstools, wood insects and bacteria.

Each thin leaf, each blade of grass is a collection of many thousand little work cells in which the carbon dioxide that is the end of all dead things and the minerals of the earth are brought together and built into sugar, starch, fat and protein substances, which can become living matter by the agency of what is alive.

The botanist sees each minute cell, sees its walls coated with a living slime, sees this studded with the green particles that give the leaf its

color, particles in which the transformation of matter takes place. He sees the arrangement by which the materials are brought to the workshops and the manner in which the finished products are removed.

The chemist watches the throng of jostling molecules pushing their way into the tiny pores on the underside of the leaf, he watches them enter the liquid of the plant cell, then he loses them until they emerge as oxygen and sugar. Just how the transition is effected he does not know. That is one of the great problems awaiting solution. The sugar turns to starch, or with the mineral matter brought from the soil is turned into protein. How this is done we do not know.

The molecules factory of the green plant cannot run without power to keep its wheels turning. The psysicist is ready to explain that: Green leaves are found only in light; in darkness the factory stops. But light is a form of energy, it can be converted into work just as the heat of burning coal can be in the steam engine. The leaves then are factories run by light in which the molecules of worn out life are put into service again. Your breath is not living matter, but it may be caught there above your head and brought to life.

If you want stories of real hunting, of life when great animals strode over the dry land, wallowed in the marshes or swam in the sea, then learn the language of the rocks. The geologist is the detective who has deciphered the strange code. Those rocks in the stream before you are older than the pyramids, older than the oldest record of man. Perhaps they were made by fine matter settling in water, or by the cooling of fiery lava poured from great rents in the quaking earth's crust millions of years before great Dinosaur fought Dinosaur in the dim past of living things.

But the chemist cannot be content to know how these rocks were made, he must know of what they were made. He and the geologist must go further and still further back into the past until they reach the beginning of the world. The geologist goes no further, but the chemist pushes still further, he must know what matter was before the world was made. In this quest he joins company with the student of the heavens and earth, the astronomer. The two go back to the time when the great sun and planets were only a fiery curtain hanging as a mist in the great space of the heavens. This the astronomer tells us was the beginning, he guesses that the contraction and cooling of this cloud gave us the sun and earth. The chemist asks how the glowing cloud came to be formed and whether the stars are growing old like other things. The astronomer can only answer that probably the stars must be growing cooler, but the age of these bodies cannot be told.

How can such a question be answered when all that comes to us is a feeble ray of light coming through billions of miles of cold space?

Then with the good help of the astronomer, the chemist and physicist set forth on the most daring quest yet tried by man, to read the story of the universe. With only that faint light that journeys to the earth from the stars to guide them they have succeeded in learning of what the stars are made.

All they could see was that light, but in it was the story of the birth and death of great suns, the story of a process so tremendous in its course that a billion years are to it but as a second is in the life of man.

This universe, from the structure of the least of all things, the parts of the atom, to the limitless boundaries of the great heavens, is for you to read. Will you go blind to all this wonder, busying yourselves with the little shallow, petty things, or will you see what is your heritage, a greater wealth than any stored in all the vaults of all the world's tresures? The token that you must show to take these treasures into yourselves is knowledge, knowledge of the sciences, not least among which is chemistry.

Teaching Chemistry in the High Schools

The following chapter on the Teaching of Chemistry in High Schools is taken from a report of the Commission on the Reorganization of Secondary Education, appointed by the National Education Association. Otis W. Caldwell was Chairman of the Committee in Science, and Clarence D. Kingsley, Chairman of the Commission. This report was published by the Bureau of Education:

The average person looks upon chemistry as a mysterious, occult science, tinged with necromancy. This almost superstitious ignorance prevents appreciation of the chemist's power to serve society. In industry it is likely to result in great economic waste through failure properly to utilize raw materials, develop by-products, and apply chemical methods of control to processes of manufacture. The high-school chemistry course in its reorganized form should attract a larger number of pupils and do much to supplant this ignorance by a measure of broad understanding.

In the past, chemical laws, theories, and generalizations have usually been taught as such, and their applications in industry and daily life have been presented largely as illustrative material. In the reorganized course, this order should be reversed. Laws and theories should be approached through experimental data obtained in the laboratory and through applications with which the pupil is already familiar and in which he has a real interest.

In the past, chemistry courses over-emphasized theories, concepts, and information of value principally to those who will pursue advanced courses. A course which emphasizes the chemistry of industry, of commerce, of the soil, and of the household furnishes a wider outlook, develops a practical appreciation of the scope of chemical service, and moreover arouses an interest which leads naturally to further study.

The war showed the lack of a sufficient number of chemists trained to work out such problems as arose in that national emergency. The reconstruction period and the new conditions of world competition in trade will increase the demand for specialists in the chemical problems of manufacture. High-school courses in chemistry should therefore be so reorganized as to arouse an interest in the science of chemistry, and thereby stimulate more and more pupils to specialize later in this and related fields.

Principal aims.—The principal aims in teaching chemistry in the high school should be—

1. To give an understanding of the significance and importance of chemistry in our national life. The services of chemistry to industry, to medicine, to home life, to agriculture, and to the welfare of the nation, should be understood in an elementary way.

2. To develop those specific interests, habits, and abilities to which all science study should contribute.

The powers of observation, discrimination, interpretation, and deduction are constantly called for in chemistry and are so used in this subject as to require a high type of abstract thinking. The principles and generalizations of chemistry are often difficult. For this reason chemistry should occur in the third or fourth year of the high school.

3. To build upon the earlier science courses, and knit together previous science work by supplying knowledge fundamental to all science. Coming after at least a year of general science, and usually also a year of biological science, the work in chemistry should further use these sciences. It should furnish a new viewpoint for the organization of science materials, and develop wider and more satisfactory unifying and controlling principles. By this means the desirable element of continuity in the science course will be secured.

4. To give information of definite service to home and daily life. This aim has been the chief influence in reorganizing high-school chemistry courses, and will undoubtedly produce further changes. The criterion of usefulness, as a basis for the selection of subject matter, should not be limited to the immediately useful or practical in a narrow sense, but should be so interpreted as to include all topics which make for a better understanding of, and a keener insight into, the conditions, institutions, and demands of modern life.

5. To help pupils to discover whether they have aptitudes for further work in pure or applied science, and to induce pupils having such aptitudes to enter the university or technical school, there to continue their science studies.

General considerations concerning content and method.—This statement is based on the assumption that chemistry will usually be given in the third or the fourth year of the four-year high school. Investigation shows that a little more than one-half of the four-year high schools present chemistry in the third year, and that pupils electing chemistry usually have had one year of general science and often a year of biological science.

(1) Difficulties.—Some difficulties in organizing courses in chemistry on the basis of individual and specific pieces of work are:

(*a*) Many of the most important principles are impossible of direct or experimental proof. They can not be demonstrated in specific, individual problems, and hence can not be grasped easily by the immature mind. These concepts must be accepted on the basis of their service to the science and the useful conclusions based upon them, for example, the assumptions of the atomic hypothesis and the rule of Avogadro.

(*b*) The number of important principles and facts is so great that organization of the information supplied by discussion, investigation, and experiment is difficult. Appreciation of the science as such is impossible until the bases for establishing relationships and controlling facts are developed.

(*c*) Many problems and questions which the pupil tends to raise involve complex phases of chemistry, or ideas too advanced for his understanding.

Some motive, some compelling desire to know, must actuate the pupil in any study which is really educative. Progress in chemistry, therefore, is dependent upon a specific purpose, a conscious need to learn the facts and their underlying causes or explanation. The educational value of any problem depends upon the degree to which the pupil makes it his own and identifies himself with it, rather than upon its concreteness, or the useful applications involved, or the familiar associations connecting it with other problems, important as these considerations are. The basis for organizing a course in chemistry should lie in the changing character of the pupil's interest and the increased intensity of his needs as a result of his growing abilities and of his increased power to direct and use them. A topic in chemistry which would have seemed abstruse and uninteresting a year or even a few months earlier may suddenly become a real problem to the pupil. Such questions as what the constitution of things really is, what properties the atoms possess, or why the volumes of gases have such simple relations to one another, may become problems of real significance to the pupil. Ultimate causes and reasons appeal to the adolescent pupil. Problems having to do with home, farm, local industries, the civic and the national welfare, are limited only by the time and energy available for their pursuit.

(2) Laboratory work.—The relation between class and laboratory work is a most important problem for the chemistry teacher. Unfortunately, theory and practice have not been properly related. Some of the reasons for this situation are:

(*a*) It is difficult to correlate recitation and experiment. One lags behind the other. The remedy is a greater flexibility in the program, so that the time may be used for either purpose as needed. There is a growing tendency to make all periods of a uniform, 60-minute length

instead of 40 or 45 minutes on some days and 80 and 90 minutes on other days. This change helps to make possible a closer correlation between experiments and the discussion of them.

(*b*) Experiments often fail of their object because of insufficient directions, failure to provide needful data, or lack of a definite and clear purpose. This needful information must be supplied, but in such a way as to stimulate interest and raise questions to be answered by the experiment itself. Some teachers prefer to take the first few minutes of each laboratory exercise in talking over the work, suggesting important questions, pointing out difficulties, and giving necessary cautions. It might be well to embody more of the information usually supplied by the text in the laboratory directions themselves, so that they would be thought-producing and stimulating rather than simply directions for manipulation and observation.

(*c*) Too many experiments involve repetition of work described in the text or have no outcome beyond the mere doing and writing in the note book. Unless the experiments contribute to the recitations and provide data or information which is used, they are largely a waste of time.

Laboratory experiments, to accomplish their purpose, must concern a problem or a question which the pupil seeks to answer because he is interested in doing so. The titles of experiments can often be worded so that they become suggestive by stating them in problem or question form. For example, instead of the title "Mordant dyeing," a better one would be, "Why are mordants used in dyeing?" Or, in place of "Equivalent weight of magnesium," substitute "How much magnesium is needed to produce a gram of hydrogen?" Or, for "Analysis of ammonia," substitute "What is the most economical brand of household ammonia to purchase?" The mere rewording of a title itself is not enough. The question itself must be a vital one to the pupil either through his own independent thought or as a result of the stimulating influence of the class discussion.

Flexibility in the keeping of notebooks is desirable, provided that the essential facts and conclusions are always included. The notes should usually include a clear statement of the problem in hand; a description of the method of procedure, making use of a diagram of such apparatus as may have been used; and a statement of results and conclusions, with answers to any specific questions which have arisen. If the pupil's notes cover this ground, they should be accepted, and he should be encouraged to work out any plan of his own for the improvement of his notebook. To require all to use exactly the same plan may make the checking of notebooks more easy and their appearance more satisfactory, but it stifles

the pupil's originality and prevents him from discovering and correcting his own faults in this direction.

The notebook has often been a fetish with chemistry teachers, and time has been demanded for making a record which, while beautiful in appearance and completeness, is yet full of needless repetition and useless detail. The notebook should not destroy the interest attached to an experiment, for the experiment is not for the notebook but for the pupil's clearer understanding of important chemical facts. Only when properly used will the notebook enhance the value of laboratory work.

The teacher in the laboratory should not set up apparatus, weigh out materials, or attend to other purely manual matters, which in most cases should be done by the pupils. The teacher should see that pupils are trained to observe accurately, to draw correct inferences, to relate their conclusions to the facts of previous experience in and out of school, and to find the answers to questions and problems brought out.

It is proper that the teacher should perform laboratory demonstrations that are too difficult, too costly in materials, or too long, for student assignment. These should be done with model technique, for the pupils will imitate the teacher's methods. They should be recorded in the student's laboratory notebook just as any other experiment, but with the notation "performed by instructor."

(3) Aids to the chemistry teachers.—(*a*) Reference books and magazines. A part of the requisite equipment of every chemistry department is a well chosen set of reference books, available and in constant use. Each pupil will need a textbook as chief reference book, but he should find it necessary to use additional books. There should be provided duplicate copies of the better textbooks, other books on special subjects, articles, newspaper clippings, etc. These books are necessary in order that the pupil may investigate all the questions that arise. He will profit by the training which comes from learning how to find the answers to his questions from many sources of information. These books should provide entertaining reading by which the pupil's interest in things chemical may be stimulated and developed.

(*b*) Individual topics and reports. The study of special topics and reports upon them by individual members should be a regular feature of the class work. Pupils should be encouraged along the line of their special interests, and lists of topics should be suggested by the teacher from time to time. By this plan individual initiative and ability may be given encouragement and the whole class stimulated.

(*c*) Optional experiments. The pupils should be given encouragement to bring in materials to test in various ways and, whenever time permits, to perform additional experiments, the results of which may be

reported to the class. In the chemistry laboratory it is not necessary or desirable that all pupils be always at work on the same experiment. Even if the experiment is essentially the same, a variety of materials may often be used, and each pupil may contribute to the general result. For example, if colored cotton cloth is to be bleached by chloride of lime, let the pupils bring in samples from home so that a variety of colors may be tried out; or, if the presence of coal-tar dyes is to be tested in candy or food products, each pupil should be responsible for his own materials. In this way the work of the class will have a breadth and scope which will make the results more significant.

(*d*) The review. In chemistry the number of detailed facts is so great, and the application of its principles so wide, that from time to time a definite plan for insuring proper organization of ideas is needed. These need not be formal reviews and tests, though such have their place, but they should always be exact and comprehensive. Quizzes should frequently follow excursions or a series of laboratory experiments upon some central topic of study. These should be conducted in such a way as to lead pupils to organize knowledge for themselves rather than to force upon them a classification of the material that does not develop from their own work.

(*e*) Excursions. Many topics in chemistry should be initiated or supplemented by an excursion to a factory or industrial plant where the operations may be viewed at first hand. If such excursions are to be really profitable, there must be a very definite plan covering the things to be seen. The first recitation after such an excursion should be devoted to answering questions suggested by what has been seen and to defining further studies based upon these observations. The great value of the excursion lies in the opportunity to give the pupil a vivid conception of the practicability of chemical knowledge and to make him see that there is a definite relation between the test tubes and beakers of the laboratory and the vats, concentrators, and furnaces of the factory.

(*f*) Science clubs. Whenever the number of students taking chemistry is sufficient to warrant the formation of a chemical club, this is desirable. The members of the chemistry class should be encouraged to join or organize a science club and to make it an attractive feature of the school life. In small schools a science section may be a part of a literary or debating society, thus widening the interests served by such an organization. Such a club provides motive and opportunity for the exercise of individual interest and effort, and the interest of the whole school may be extended through it.

Specific principles controlling reorganization.—1. Larger units of study.—The number of important principles and facts in chemistry is

so great that there is grave danger that many topics will remain isolated and unorganized in the mind of the student. Reorganization should develop larger units of study connected by and emphasizing natural relationships.

(*a*) These larger units of study should be presented in such a manner as to appeal to the pupil personally.

Interest is not likely to be aroused if the more important elements are taken up in the order suggested by the periodic system. It is equally destructive of enthusiasm to use one unvarying plan of study with every element, as occurrence, physical and chemical properties, methods of obtaining, uses, important compounds, etc.

(*b*) The selection of these large topics should not be handicapped by the traditional content of the course. Traditional divisions should be retained only when they are found to aid the pupil in making his own organization of the facts and principles involved.

Such topics should show many cross relationships, necessitating the use of information previously gained in new situations and serving to fuse all into an organic whole. Thus, sudden leaps into absolutely new material would be avoided or at least greatly reduced.

As an illustration, the interesting, unified, and vitally significant topic of fertilizers can be developed out of information usually supplied under such isolated headings as nitrogen, phosphorus, potassium, sodium, calcium, sulphur, carbon, etc.

(*c*) Certain topics of chemistry cover wide fields. The large topic is valuable because it shows broad relations and secures the right sort of organization in the mind of the pupil. Neutralization, hydrolysis, oxidation, etc., are examples of such topics, which are constantly recurring in new phases and which should be brought out not once but many times.

2. Laws and theories.—A chemical law or theory should be taught as a generalization, justified by experimental data, or as a device to explain things that the pupil is eager to understand. Likewise, chemical mathematics should be developed through problems arising from the laboratory work or through practical problems that the chemist is called upon to solve in everyday situations.

Content.—Different introductory courses in chemistry contain much in common in that they deal with fundamental facts, concepts, laws, and theories, but the teaching of these fundamentals must be influenced by the particular conditions and purposes which control in the individual school. It is not the purpose of the committee to lay out the work in detail or to offer a syllabus, but to suggest by a few type topics the character of the organization recommended. These have been selected

solely as illustrations, and no sequence is implied by the order in which they appear here.

1. The atmosphere. (A sample introductory topic.)—(*a*) Physical properties. Recall, or perform demonstration experiments to show, that air possesses weight, exerts pressure, expands when heated, and is compressible. Demonstrate diffusion of gases by spilling ammonia. Development in simple way of kinetic molecular hypothesis as basis for explanation. Demonstration experiments to illustrate Boyle's and Charles's laws, if needed.

(*b*) Air and burning. How does a candle burn? Structure of flame: Products of combustion, identification of water by condensation, soot by deposit on cold objects, and carbon dioxide by reaction with lime water. (Water may be electrolyzed to show its composition.) Definitions of element, compound, mixture, and chemical changes. Fuels: Composed chiefly of carbon and hydrogen. Prove by burning coal, gasoline, kerosene, gas, wood, etc. Luminosity of flame due to carbon. Kindling temperature.

(*c*) Oxygen. Laboratory study of oxygen and burning in oxygen contrasted with that in air. Action on metals.

(*d*) Composition of air. Analysis, using phosphorus and iron filings. Residual nitrogen tested for effect on combustion. Nitrogen as diluting material in air. Is it fortunate air is not all oxygen?

(*e*) Other questions to be considered or used for assignment purposes: How was oxygen discovered? How abundant is it? How are rusting and decay different from burning? How is spontaneous combustion caused? What precautions should be used to avoid it? Why is perfect combustion desirable in furnaces and steam-power plants? Why is imperfect combustion dangerous in stoves or grates? Oxyacetylene process for welding and cutting. How is oxygen prepared for commercial purposes? Oxygen as necessary to life. Ventilation for health and comfort. Corrosion of metals, causes and prevention.

2. Purification of water.—(*a*) Importance of the question from standpoint of health and industry.

(*b*) Common impurities and their removal: Sedimentation and filtration for suspended matter; boiling to destroy bacteria; coagulation to remove sediment and bacteria (use alum and lime water); distillation to remove dissolved minerals; chlorination with bleaching powder (chloride of lime; add solution of bleaching powder to water and taste); tests for sulphates, chlorides, calcium compounds, and organic matters; laboratory testing of spring and mineral waters collected by pupils.

(*c*) How cities get pure water: Protecting the catch basin (New

York); sedimentation and filtration methods (St. Louis); coagulation and precipitation method (Columbus); demonstration experiments to illustrate; excursion to local pumping station and study of system of purification employed.

(*d*) Soft and hard water, temporary and permanent varieties; effect of hard water in tubes of steam boilers (specimens of boiler scales); why a laundry needs soft water; action of hard water on soap; softening power of borax, ammonia, soda, soap, and washing powder of various brands.

(*e*) Sewage disposal: Relation to pure water supply of other cities or communities; dilution method (Chicago drainage canal); oxidation methods (spraying, activated sludge); methods for small towns and rural homes; the septic tank.

3. Limestone, lime, and allied products.—(This topic is developed in considerable detail, suggesting a possible plan for correlating laboratory and classroom work, excursions, and individual reports, and showing how drill in equation writing and problem solving may naturally arise.)

IN THE LABORATORY.

1. Excursion to limestone bluff or quarry. Collection and display of limestone fossils. Observe, on the way, any limestone or marble used in buildings. Visit limekiln and hydrating plant if possible.

2. Note texture, solubility, reaction to moist litmus, and effect of acid on a limestone lump. Heat the lump, note changes in the above properties.

3. Using quicklime, note heat on solution, reaction to litmus, etc. Pour the following mixtures in the form of thick pastes, into match-box molds: (1) Lime and water; (2) lime and sand and water; (3) lime, sand, cement, and water. Allow to stand until hardened. Examine these specimens for suitability as mortar. Test these specimens, also old mortar, with acid. Test evolved gas. Examine both in place and as laboratory specimens, samples of mortar, plaster, concrete, reinforced concrete.

IN THE CLASSROOM.

1. Discussion and explanation of the mode of limestone deposit. Observation of fossil shells, corals, skeletons. Reference to geology text. Study of metamorphic limestone (marble) and uses of marble and limestone in buildings.

2. Discuss visit to limekiln, or use diagrams. Describe use of "limelight" in stereopticons, etc. Derivation of the phrase "to seek the limelight."

3. Make sure that the students can write equations, and fully understand the chemical reactions from limestone, calcium carbonate as quarried, to calcium carbonate as the final product in mortar or concrete. Prepare and discuss the following special reports: "Manufacture of lime in large quantities;" "Manufacture of hydrated lime;" "The use of lime as a disinfectant;" "The use of lime (limewater) in medicine;" "Use of lime in whitewash;" "Source and manufacture of cement;" "The use of mortar and concrete in the construction of walks, buildings, bridges,

posts, pipes, tile, furniture;" "The proportions of different ingredients, the erection and filling of forms, mixing machines, etc.—the reports of an interview with a practical plasterer, and concrete foreman;" "Artificial building stone."

4. Note properties of a piece of native gypsum. Heat a crystal, note water driven off and change in form. Pour thick paste of plaster of Paris into a match box, and press into it some object such as a nut, small brass ornament, or small clay model, previously greased with vaseline. Let paste harden thoroughly.

4. Discuss occurrence of gypsum. Equations for heating gypsum and for setting of plaster of Paris. Prepare and discuss special reports: "Manufacture of plaster of Paris" on a large scale; "Uses of plaster of Paris in molds, statuary, for broken bones, white coat for plaster, etc.;" "Manufacture and uses of calcimine."

5. Test the solubility of a limestone lump in (*a*) distilled water; (*b*) rain water; (*c*) distilled water into which carbon dioxide has been passed to acidity. Filter and test for calcium with ammonium oxalate. Pass breath through limewater. Burn a splint in a bottle, add limewater, and shake. Pass carbon dioxide through limewater until the precipitate is redissolved.

5. Discuss solubility of limestone in carbonated rain water. Special report: "The formation of caves and sink holes;" "The formation of stalactites and stalagmites." The limewater test for carbon dioxide. Equations for these processes.

6. Shake any of above solutions in which some limestone has dissolved with soap solution, adding drop by drop. Prepare the following samples: (*a*) Distilled water; (*b*) bubble carbon dioxide through water, and shake with ground limestone, filter; (*c*) add several drops of saturated calcium sulphate solution to water; (*d*) hydrant water. To one-third of each add soap solution (approximately Clarke's standard) from burette and record amount needed to form suds. Boil one-third of each vigorously. Observe any precipitate. Filter and add soap solution as before. To one-third of each add a few cc. of washing soda solution, then soap solution as before.

Test the effect of other softening agents—ammonia, borax, lime, commercial softening agents, and boiler preparations.

6. Discussion of temporary and permanent hardness. Methods of softening each. Complete set of equations. (This is an excellent exercise on interpretation of results.) Require special reports: "Household experience in the use of river and spring water in washing and cooking;" "The use of hard water in boilers" (illustrated with specimens of boiler scale); "Comparative cost of softening water with different agents, including soap;" "What are commercial softening agents composed of?"

It is believed that the softening power of washing soda is more logically discussed under this heading than in the chapter on "Sodium," and that "Hardness of water" should be treated in detail here unless included in such a topic as the "Purification of water," previously outlined. At any rate, the cross reference should be made, the facts reviewed, and the principles extended to the new topic.

7. Test solubility of powdered limestone in weak acids—dilute hydrochloric, carbonic, citric.

Test soil in a swampy place for acidity, sprinkle with powdered limestone and test several days later.

Extract soil with HCl—burn bones and extract ash with HCl—coagulate milk, filter—and test all filtrates for calcium with ammonium oxalate.

Examine face powder, testing for chalk or gypsum.

Examine blackboard crayon.

7. Special reports and discussions: "What causes acid soils?" "What crops will not grow in acid soils?" "The use of ground limestone (and plaster) on acid soil;" "An interview with a progressive farmer or fertilizer salesman on method of calculating the amount of limestone needed per acre of soil;" "The presence of calcium compounds in plant and animal tissues;" "Use of powdered limestone for miscellaneous purposes."

4. Simple inorganic preparations.—The introduction of simple inorganic preparations to the laboratory work of the second half of the year furnishes every desirable opportunity for the bright pupil to test his ability. It gives him a chance to do extra work, learn additional chemistry, and gain considerable skill in manipulation. The materials for this work include: Copper sulphate from copper scraps; copper nitrate as by-product from preparation of nitric oxide; ammonium-copper sulphate from copper sulphate; mercurous nitrate and mercuric nitrate from mercury; boric acid from borax; zinc sulphate as a by-product of the preparation of hydrogen; sodium thiosulphate from sodium sulphate; mercuric sulphocyanide from mercuric nitrate; zinc oxide from zinc sulphate; and potassium nitrate from wood ashes.

It has been demonstrated that the pupils are greatly interested in such experiments and spend many hours willingly in completing these preparations.

The committee does not desire to outline other topics in detail, since too much elaboration might tend to retard rather than stimulate the proper reorganization of the chemistry course. The following list is added to show a great variety of interesting topics which may be drawn upon for illustrative and informational purposes and for developing the fundamental generalizations of chemistry. Local conditions, the interest and needs of the particular class, and the time available should determine the choice of such topics and their proper organization into the larger units of study. The following list could be greatly extended:

Glass.—Crown, flint, lead, special glasses, coloring of glass.

Clay products.—Brick, pottery, chinaware, porcelain.

Artificial stone.—Lime, plaster, mortar, hydraulic cement, concrete stucco, plaster of paris.

Fertilizers.—Problems of soil fertility, elements needed by growing plant and function of each. Photosynthesis and carbon dioxide cycle. Nitrogen cycle and function of nitrogen fertilizers. Use of limestone and phosphate rock.

Coal.—Composition and fuel values of different varieties. Distillation of coal

tar, light oil, middle oil, heavy oil, tar, pitch. Relation to dyes and explosives.

Petroleum.—Fractional distillation into burning oils, solvent oils, lubricants, paraffins. Problem of gasoline supply and possible exhaustion of petroleum.

Wood.—Distillation of wood to produce methyl alchol, acetone, acetic acid, charcoal.

Explosives.—Black powder, nitroglycerine, dynamite, guncotton, trinitrotoluene. Relation to nitrogen fixation by arc, Haber, and cyanide processes.

Paint, varnish, etc.—Oil paints and driers, varnish, shellac, copal. Linseed oil, oilcloth, linoleum.

Pigments.—White lead, red lead, iron oxide, lead chromate, etc.

Textile fibers.—Natural and artificial silk. Wool: Scouring, bleaching, felting, etc. Cotton: Bleaching, mercerizing, etc.

Dyeing.—Direct and mordant dyes.

Cleansing agents.—By acid: Oxalic, hydrochloric. By alkalies: Caustic soda, soap emulsification. By special solvents: Carbon tetrachlorid, benzene. Composition of trade-marked cleaning fluids.

Photography.—Blue prints, plates, films, prints, toning, etc.

Food constituents.—Starch preparations from corn; cooking: to dextrin and to paste, hydrolysis to glucose.

Sugars.—Preparation and refining of beet and cane varieties; conversion to caramel; inversion.

Fats.—Olive oil, cottonseed oil, butter, oleomargarine, hardening oils by hydrogenation.

Proteins.—Albumins, casein, gluten, peptones, gelatines, vitamines.

Beverages.—Charged waters, soda, mineral, infusions, tea, coffee, chocolate.

Fruit juices (artificial flavors), fermentation.

Poisons and common antidotes.—Common inorganic drugs.

Leavening agents.—Yeast, soda, baking powders.

Matches.—Ordinary and safety types.

Adhesives.—Gums, paste, dextrin, glue, casein, water glass (sodium silicate).

Inks.—Various types.

Refuse disposal.—Sewerage, garbage; fermentation and putrefaction; civic problems; disinfectants and deodorizing agents.

Preserving.—Sterilizing, pasteurizing, desiccating, pickling by salt and sugar; chemical preservatives and tests for them.

Metals.—Extraction processes; oxide ore, iron, sulfid ore, lead; electrolysis, sodium and aluminum; extraction of other metals may be studied by comparison with these.

Metals used for basic purposes, iron, copper, aluminum, lead; for ornament, gold, silver, nickel; for alloys, bronze, brass, solder, type metal, antifriction or bearing metals, fusible metal.

Differentiated chemistry courses for certain curriculums.—The content of the regular course in chemistry has been indicated in the two sections just preceding. It is designed to meet the needs of young people and to enable such as need it to count the work done for college entrance. It remains to show how modified chemistry courses may be offered to meet the requirements of special groups of pupils by including topics and problems bearing more directly on the work these pupils will enter or in which they are already engaged. These differentiated

courses are chiefly of two types, those which aim to better prepare girls for home making and home management and those offered in technical curriculums to suit the needs of students primarily interested in industry. These two types are briefly considered.

1. Courses in household or domestic chemistry.—There are two methods which are followed in teaching household or domestic chemistry. Girls may be taught the regular chemistry the first half of the year and the second half they may be given instruction in topics relating directly to the home, or a year's course in household chemistry may be given. Each school should choose the method best adapted to its organization. If a year's course of household chemistry is given, the first half should emphasize the study of chemical change, combustion, water, air, acids, bases, salts, and chemical formulas. In the second half the following topics should be emphasized: Carbon compounds in their relation to fuels, cooking, and foods; metals used in the home, as iron, copper, aluminum, and silver; textiles and cleaning agents; dyeing and removal of stains; fertilizers and insecticides; disinfectants and antiseptics; poisons and their antidotes; paints and varnishes.

2. Courses in technical curriculum.—In many technical curriculums there is a demand for a two or three years' course in chemistry. In such cases the elementary course is given in the tenth or eleventh year, followed by qualitative analysis and organic chemistry. Some teachers may prefer to give in the second year a half year of advanced general chemistry and a half year of qualitative analysis. In addition to these, special courses for certain types of students should be offered if there are facilities and if there is sufficient demand for the work. To illustrate, a few courses which have been successfully tried in the continuation and evening classes of a large technical high school are described:

(*a*) Chemistry for nurses: Girls who study nursing find it of great advantage to know something of the fundamental principles of chemistry. Many of the girls have not completed a high school course and have not studied chemistry. For such girls a special course consisting of laboratory work and discussion two afternoons a week for 13 weeks is given. This course covers elementary chemistry through carbon compounds, and emphasis is placed on the study of substances used as drugs and in the home.

(*b*) Chemistry for electroplaters: A large percentage of men actually engaged in the electroplating of metals have only a common school education, and their work is done mechanically. Without a knowledge of the fundamental principles of chemistry and electricity the men find much difficulty in solving their problems. To remedy this condition the National Society of Electroplaters has been organized. At least

one technical high school has been coöperating with this organization the past two years. A special class for electroplaters has been conducted in the evening school. The men study elementary chemistry, electricity, and volumetric analysis and discuss their problems with the instructor. The students are very enthusiastic over the course and they have become more intelligent and skilled workers.

(*c*) Chemistry for pharmacy: Some high schools offer a course in pharmacy. For this purpose a three-year course in chemistry is desirable. The first year the pupils study elementary chemistry, which differs from the regular course by emphasis on technique, preparation of tinctures and ointments, the study of drug manufacturing, and chemical arithmetic. Qualitative analysis is studied the second year, quantitative analysis and organic chemistry the third year.

(*d*) Special courses for workmen and foremen in chemical industries: Some manufacturers permit their employees to study in technical high schools for one afternoon a week in order to make them more intelligent workers. The chemistry course in these cases is adapted to the needs of the individuals. Where facilities permit there is opportunity for great service to the men and the community. A course in simple, inorganic preparations such as ammonium, sodium, and potassium compounds, is valuable to teach in connection with or following the elementary course.

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